Feature

Using Artificial Intelligence Planning to Automate Image Processing

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Recent breakthroughs in imaging technology have led to an explosion of available data in image format. However, these advances in imaging technology have brought with them a commensurate increase in the complexity of image processing and analysis technology.

Processing complexities

When analyzing newly available image data to discover patterns or to confirm scientific theories, a complex set of operations is often required. First, before the data can be used it must often be reformatted, cleaned, and have many correction steps applied. Then, in order to perform the actual data analysis, you must manage all of the analysis software packages and their requirements on format, required information, etc. Furthermore, this data analysis process is not a one-shot process. Typically a scientist will set up some sort of analysis and study the results. Then the results will be used to modify the analysis, to improve it. This analysis and refinement cycle may occur many times. Thus any reduction in the effort or cycle time can dramatically improve scientists' productivity.

Consider the goal of studying the soil sediment transport (wind erosion patterns). In order to do this the scientist uses a z0map (described later) to analyze the surface wind velocities using synthetic aperture radar (SAR) data. In order to generate the z0map, the scientist must go through a number of processes:

- data acquisition—getting the data from a proprietary tape format using the Committee on Earth Observing Sensors reader software package
- data conversion—the data must be decompressed using yet another software package
- preprocessing—header and label files must be added to the data files
- processing—using the z0map software package, a z0map image is created
- post processing—depending on the desired data format, the z0map image files may need to be converted to Video Image Communication and Retrieval (VICAR) format (yet another proprietary format)

Unfortunately, this data preparation and analysis process is both knowledge and labor intensive. Correctly producing this science product for analysis requires knowledge of 1) the particular science discipline of interest (e.g., atmospheric science, planetary geology), 2) image processing, and 3) the image processing libraries available. Also required are an understanding of where and how the images and associated information are stored (e.g., calibration files) and the overall image processing environment, to know how to link together libraries and pass information from one program to another.

It may take many years of training and expertise to acquire the breadth of knowledge necessary in all areas to perform these analyses. Such experts are in high demand. Additionally, considerable knowledge of software infrastructure is desirable, such as knowing how to specify input parameters (format, type, and options) for each software package being used and how to translate information from one package to another, which may take considerable effort. Using automated planning technology to represent and automate many of these data analysis functions [1:p.50], [2] enables novice users to utilize software libraries to prepare and analyze data. Such technology also allows the user who may be expert in some areas but less knowledgable in others to use the software tools.

Planning-technology elements

To address the knowledge-based software reconfiguration problem in general, and science data analysis in specific, techniques from artificial intelligence planning were applied and extended.[1] Planning technology relies on an encoding of possible actions in the domain. In this encoding,you specify for each action in the domain: preconditions, post-conditions, and sub-activities.

Preconditions are requirements that must be met before the action can be taken. These may be pieces of information that are required to correctly apply a software package, such as the image format, availability of calibration data, etc. Postconditions are things that are made true by the execution of the actions, such as the fact that the data has been photometrically corrected (corrected for the relative location of the lighting source) or that 3D topography information has been extracted from an image. Sub-activities are lower level activities that comprise the higher level activity.

For an example of sub-activities, let us return to our previous example of analyzing soil sediment transport using SAR data, the different tasks (e.g., data acquisition, data conversion, etc.) are considered subtasks of the overall product generation process. The planner begins with the process of "determining parameters." This in turn is driven by the type of data format or mode of the SAR during data collection. Through this decomposition process parameters to be used in the z0map calculation are initialized. Given this encoding of actions, a planner is able to solve individual problems, where each problem is a current state and a set of goals. The planner uses its action models to synthesize a plan (a set of actions) to achieve the goals from the current state.

Planning consists of three main mechanisms: subgoaling, task decomposition, and conflict analysis. In subgoaling, a planner ensures that all of the preconditions of actions in the plan are met. This can be done by ensuring that they are true in the initial state or by adding appropriate actions to the plan. In task decomposition, the planner ensures that all high level (abstract) activities are expanded so that the lower level activities (sub-activities) are present in the plan. This ensures that the plan consists of executable activities. Conflict analysis ensures that different portions of the plan do not interfere with each other.

1.For more details on planning technology see [3], [4].

An automated processing system

The Automated SAR Image Processing (ASIP) system[2] is an end-to-end image processing system that automates data abstraction, decompression, and (radar) image processing subsystems, and intelligently integrates a number of SAR and z0 image processing subsystems. ASIP automates synthetic aperture radar (SAR) image processing based on user request and a knowledge-base model of SAR image processing using artificial intelligence (AI) automated planning techniques. SAR operates simultaneously in multipolarizations and multifrequencies to produce different images consisting of radar backscatter coefficients (s0) through different polarizations at different frequencies.

Using a knowledge base of SAR processing actions and a general purpose planning engine, ASIP reasons about the parameter and subsystem constraints and requirements. In this fashion ASIP extracts needed parameters from image format and header files as appropriate, relieving the need to know these aspects of the problem. These parameters, in conjunction with the knowledge-base of SAR processing steps and a minimal set of required user inputs (entered through a single graphical user interface), are then used to determine the processing plan.

ASIP represents a number of processing constraints. For example, ASIP represents the fact that only some subset of all possible combinations of polarizations are legal (as dependent on the input data). ASIP also represents image processing knowledge about how to use polarization and frequency band information to compute parameters used for

Constructing maps

ASIP enables construction of aerodynamic roughness image/maps (z0 map) from raw data, enabling studies of Aeolian processes. The aerodynamic roughness length (z0) is the height above a surface at which a wind profile assumes zero velocity. z0 is an important parameter in studies of atmospheric circulation

2. For more detail on the ASIP sytem see [5].

and aeolian sediment transport (in layman's terms: wind patterns, wind erosion patterns, and sand/soil drift caused by wind) [6], [7], [8]. Estimating z0 with radar is beneficial because large areas can be mapped quickly to study aeolian processes, as opposed to the slow and painstaking process of manually taking field measurements [9]. The final science product is a VICAR image called a z0 map that scientists use to study the aeolian processes. The z0map figure shows an aerodynamic roughness length map of a site near Death Valley, California, generated using the ASIP system (the map uses the L band (24 cm) SAR with HV polarization). Each of the color bands indicated signifies a different approximate aerodynamic roughness length. This map is then used to study aeolian processes at the Death Valley site.

Conclusions

Since the ASIP system has been fielded, it has proven to be useful for generating aerodynamic roughness maps, with three major benefits. First, ASIP has enabled a 10 fold reduction in the number of manual inputs required to produce an aerodynamic roughness map. Second, ASIP has enabled a 30% reduction in CPU processing time to produce such a map. Third, and most significantly, ASIP has enabled scientists to process their own data (previously programming staff were required). By enabling scientists to directly manipulate the data, and reducing processing overhead and turnaround, science is directly enhanced.

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To view an Aerodynamic roughness length map produced using the Automated SAR Image Processing System access:

http://www-aig.jpl.nasa.gov/planning/asip

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